EXECUTIVE SUMMARY

AIRCRAFT ACCIDENT INVESTIGATION

MH-53M, S/N 69-05794
HURLBURT FIELD, FLORIDA
7 SEPTEMBER 2007

On 07 September 2007, at 2349 local time, an MH-53M helicopter, serial number (S/N) 69-05794, sustained extensive damage while making an emergency landing to Landing Zone (LZ) X-ray, Eglin Range Complex, Florida, while conducting unilateral night vision goggle (NVG) alternate insertion/extraction (AIE) training. The MH-53 was assigned to the 20th Special Operations Squadron, 1st Special Operations Wing, Hurlburt Field, Florida. None of the seven crewmembers were seriously injured, the aircraft sustained $8.6M in damage, and there was no damage to private property.

Following 1.2 hours of flying training, the mishap aircraft (MA) departed Hurlburt Field at 2336 local time to conduct night vision goggle (NVG) hoist training at LZ X-ray. Twelve minutes after takeoff, the mishap crew (MC) was in a high hover at approximately 75-150 ft east of the LZ, well above all trees in the vicinity. The mishap tail scanner (MTS) sensed a worsening vibration and called for a "go around." The mishap copilot (MCP) initiated a takeoff from the hover, and within seconds, every crewmember sensed an obvious malfunction. The mishap pilot (MP) assumed control of the MA and initiated a right turn back to the LZ for an immediate landing.

It took approximately 45 seconds to return to the LZ. In that time, the MC observed abnormal oscillations in the engine and rotor instruments, commensurate with audible changes in rotor and engine speed, progressively increasing in magnitude. As the MA cleared the trees, the rotor speed had decreased to 70%. The MP lowered the collective to regain rotor speed, which put the MA into a rapid decent. At 20-25 feet above the LZ, the MP pulled up full collective to cushion the landing, which induced a rapid right yaw due to the loss of anti torque effectiveness and drive. The MA was damaged extensively when it contacted the ground.

There is clear and convincing evidence this mishap was caused by the material failure of some of the mounting nuts and studs which secure the intermediate gear box (IGB) to the tail pylon of the aircraft. The loose gear box allowed the IGB internal gears to cyclically become loosely meshed (possibly unmeshed) and re-meshed, inducing an abnormal oscillation in the speed of one or both engines, which forced the crew to make an emergency landing.

SUMMARY OF FACTS AND STATEMENT OF OPINION
MH-53M S/N 69-05794 ACCIDENT
7 SEPTEMBER 2007

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COMMONLY USED ACRONYMS & ABBREVIATIONS

AC	Aircraft Commander
AF	Air Force
AFB	Air Force Base
AFI	Air Force Instruction
AFCS	Automatic Flight Control System
AFSOC	Air Force Special Operations Command
AFTO	Air Force Technical Order
AGL	Above Ground Level
AIE	Alternate Insertion Extraction
AOR	Area of Responsibility
APP	Auxiliary Power Plant
ATC	Air Traffic Control
BPO	Basic Post-Flight Operation
Chalk	Element in aircraft formation
CMFD	Color Multifunction Display
CRM	Crew Resource Management
DS	Drive Shaft
EEMT	End Effective Nautical Twilight
EMS	Emergency Medical Services
ENS	Enhanced Navigation System
EP	Emergency Procedures
ER	Emergency Room
ETL	Effective Translational Lift
FCF	Functional Check Flight
FE	Flight Engineer
FLIR	Forward Looking Infrared
G	Gravitational Unit
HLZ	Helicopter Landing Zone
IAW	In Accordance With
IDMT	Independent Medical Duty Technician
IFR	Instrument Flight Rules
IGB	Intermediate Gear Box
IGE	In Ground Effect
ILS	Instrument Landing System
IP	Initial Point
JOC	Joint Operations Center
KIAS	Knots Indicated Airspeed
L	Local Time
LTE	Loss of Tail Rotor Effectiveness
LZ	Landing Zone
MA	Mishap Aircraft
MC	Mishap Crew
MEDEVAC	Medical Evacuation
METL	Mission Essential Task List
MP	Mishap Pilot
MCP	Mishap Copilot
MFE	Mishap Flight Engineer
MFS	Mishap Flight Surgeon
MGB	Main Gear Box
MRS	Mishap Right Scanner
MLS	Mishap Left Scanner
MTS	Mishap Tail Scanner
MSL	Mean Sea Level
Nf	Engine Power Turbine Speed
Ng	Engine Gas Generator Speed
Nr	Rotor Speed
NVG	Night Vision Goggles
OCF	Operational Check Flight
OGE	Out of Ground Effect
OPCON	Operational Control
OTI	One Time Inspection
Pavelow	MH-53M Aircraft
PRC112	Hand held survival radio
Rad Alt	Radar Altimeter
RPM	Revolutions Per Minute
RTB	Return to Base
SEAS	Single Engine Airspeed
SERE	Survival, Evasion, Resistance Escape training
SIM	Flight Simulator
S/N	Serial Number
SOP	Standard Operating Procedure
SOW	Special Operations Wing
TAC	Tactical
TCTO	Time Compliance Technical Order
TGB	Tail Gear Box
TO	Technical Order
TOLD	Takeoff and Landing Data
USAF	United States Air Force
VMS	Vibration Management System
VRSP	Voltage Regulator Supervisory Panel
Z	Zulu Time Zone or Greenwich Mean Time (GMT)

The above list was compiled from the Summary of Facts, the Statement of Opinion, the Index of Tabs, and witness testimony (Tab V).

SUMMARY OF FACTS

1. AUTHORITY, PURPOSE, AND CIRCUMSTANCES

a. Authority.

On 8 September 2007, Major General Donald C. Wurster, Vice Commander, Air Force Special Operations Command (AFSOC) appointed Colonel Scott B. Greene to conduct an aircraft accident investigation of the 7 September 2007 crash of an MH-53M aircraft, serial number (S/N) 69-05794, at landing zone (LZ) X-ray, Eglin range, Florida. The investigation was conducted at Hurlburt Field, FL, from Tuesday 9 October 2007 through 1 February 2008. Board members were Lieutenant Colonel (Lt Col) Lee H. Harvis (Medical), Major (Maj) Deirdre A. Kokora (Legal), Maj Roy H. Oberhaus (Pilot), Maj Michael S. Stohler (Maintenance), Captain (Capt) David M.C. Lucas (Recorder), Technical Sergeant (TSgt) Frizi S. Anthony (Administrative Specialist). Experts appointed to assist the board were Mr. Jim Sawinski,(MH-53 Aero Engineer), 580 ACSSS/GFEAD, and SSgt Brett Saylor, (Crew Chief), 373 TRS/TXED (Tabs Y-1, Y-2, Y-3).

b. Purpose.

This aircraft accident investigation was convened under Air Force Instruction (AFI) 51-503, *Aerospace Accident Investigations*. The purpose of this document is to provide a publicly releasable report of the facts and circumstances surrounding the accident; to include a statement of opinion on the cause or causes of the accident; to gather and preserve evidence for claims, litigation, and disciplinary and administrative actions; and for all other purposes. In addition to setting forth factual information concerning the accident, the board president is also required to state his opinion as to the cause of the accident or the existence of factors, if any, which substantially contributed to the accident. This investigation is separate and apart from the safety investigation, which is conducted pursuant to AFI 91-204, *Safety Investigations and Reports*, for the purpose of mishap prevention. The report is available for public dissemination under the Freedom of Information Act. Title 5 United States Code (U.S.C.) Section 552, and the Air Force Supplement to Department of Defense (DoD) Regulation 5400.7-R, *DoD Freedom of Information Act (FOIA) Program*, 24 June 2002.

c. Circumstances.

The accident board was convened to investigate the Class A accident involving an MH-53M aircraft, S/N 69-05794, assigned to the 20th Special Operations Squadron (20 SOS), 1st Special Operations Wing (1 SOW), Hurlburt Field, FL, which was damaged while making an emergency landing on 7 Sept 2007.

2. ACCIDENT SUMMARY

Aircraft MH-53M, S/N 69-05794, experienced a malfunction which required an emergency landing during a night vision goggle (NVG) aided training flight on 7 Sept 2007. During the emergency landing, the aircraft lost yaw control inducing a rapid clockwise rotation. The aircraft was extensively damaged during the landing at LZ X-ray, Eglin Range, FL (Tab B-3). The MC egressed safely and suffered minor to moderate injuries including a leg fracture, back pain, bruises, abrasions, and contusions. The aircraft sustained significant damage upon impact with the loss valued at $8,651,469.22 (Tab P-3, Tab P-4). Other than damage to the aircraft, damage to government property consisted of a fuel spill into the soil of the LZ due to auxiliary fuel tank rupture (Tab P-8). There was no damage to private property, nor were there any military or civilian casualties. Media interest consisted of several national, regional, and local newspaper articles and broadcasts. Media interest was fielded through Hurlburt Field Public Affairs offices (Tab CC-2.1).

3. BACKGROUND

The 1 SOW, located at Hurlburt Field, FL, maintains the MH-53M Pavelow, MC-130H Combat Talon II, MC-130P Combat Shadow, AC-130H and AC-130U Gunships, CV-22 Osprey, UH-1N Huey, and U-28A aircraft. The 20 SOS is a component of the 1 SOW. The wing and its subordinate units are all components of Air Force Special Operations Command.

The 20 SOS employs the MH-53M Pavelow helicopter. Its specialized missions consist of day and night low level penetration of hostile territory to conduct clandestine infiltration and exfiltration, aerial gunnery support, and re-supply of special operations ground forces worldwide. These operations include tactical low-level navigation, NVG operations, alternate insertion and extraction methods, and over water operations. The unique capabilities of the MH-53M Pavelow allow the 20 SOS to operate from unprepared landing zones in any type of weather or terrain. The MH-53M Pavelow is also shipboard capable to include a modification that allows for blade and tail folding.

The Air Force H-53 helicopters have been in service since the late 1960's and will be phased out of the inventory as of 1 Oct 2008. Many of the aircraft have been in service for well over 12,000 flight hours. Despite the pending retirement of Air Force MH-53 aircraft, all MC interviewed reported Pavelow operations and maintenance personnel remain dedicated to the mission (Tab V-1.19-1.20, 3.47-3.50, 5.21-5.22, 7.14, 8.21, 9.14).

The three basic aerodynamic movements of any aircraft are roll, pitch and yaw. In order to explain these three movements, imagine three lines running through an aircraft and intersecting at right angles at the airplane's center of gravity. Rotation around the longitudinal axis is roll (left and right). Rotation around the side to side axis is pitch (nose up and down). Rotation around the vertical axis is yaw (nose left and right). All helicopters have the same basic flight controls: a collective stick, a cyclic stick, and anti-torque pedals. The cyclic stick provides control of the forward, backward, left and right movement of the aircraft, and typically comes through the floor between each pilot's legs and is operated using the right hand. The collective control gets its name because it controls the pitch of all the rotor blades at the same time, regardless of where the blade is as the rotor head turns. The collective stick, one on the left side of each pilot, controls movement perpendicular to the rotor disk plane. If the rotor disk plane is level and the pilot pulls up on the collective, the aircraft will climb; if he pushes down on the collective, the aircraft will descend. The pedals are used for anti-torque control, turn coordination, and turns about a vertical axis while in a hover. Anti-torque pedals control the yaw or movement around the vertical axis of the aircraft. This input is typically transmitted directly to the tail rotor. Pushing the right pedal moves the nose of the aircraft right and the tail left, and left pedal moves the nose left and the tail right. Anti-torque pedals are used to taxi the aircraft on the ground and alter aircraft heading in a hover and in forward flight.

In the event of certain aircraft malfunctions, helicopters utilize the aerodynamic principle of autorotation to land safely. Fixed wing airplanes can glide using the lift produced by their forward movement and the airflow over the wings. Helicopters don't have the same glide characteristics and must maintain the rotation of the main rotor system or rotating "wings" to produce lift.

On the MH-53M helicopter, if the engines fail in flight, the pilot must reduce the pitch in the blades to "flat pitch" by lowering the collective stick to its lowest point. If the pitch is not taken out soon enough, the rotor will slow due to the drag on the blades, the aircraft will lose lift, and the pilot will lose control of the aircraft. At flat pitch, the drag on the blades is at a minimum, and the rotor can spin freely. The aircraft will descend at a high rate and at a steep angle. As it descends, the air passing upward through the rotor blades will drive – or autorotate – the rotor just as a child's helicopter toy or seed pod will spin as it falls through the air. It takes airspeed, altitude, and skill to properly autorotate the aircraft to a safe landing. As the aircraft approaches the intended landing site, the pilot moves the controls and uses the rotor speed to produce enough lift to flare to a shallower angle and reduced rate of descent, and to cushion the landing by pulling collective (increasing pitch on the blades).

An autorotation is also required in the event of loss of tail rotor drive while in flight. If the tail rotor is no longer being driven by the engines, typically due to a mechanical failure in the drive train, the helicopter will spin uncontrollably. To stop the spin, the pilot must enter an autorotation. The maneuver is flown in the same manner as in a dual engine failure, except the pilot must turn the engines off prior to cushioning, or the aircraft will start to spin again as the collective is increased to cushion the landing.

The aircraft is powered by two General Electric (GE) T-64-100 engines, which drive the main rotor and tail rotor through a series of gearboxes and drive shafts. To drive the tail rotor, engine torque is transmitted to the main gearbox and then to the tail rotor drive shaft. The tail rotor drive shaft transmits the torque to the intermediate gearbox (IGB), located at the base of the tail rotor pylon. The IGB changes the angle of the drive shaft and provides a reduction in revolutions per minute (RPM). From the IGB, a pylon drive shaft extends upward to the tail rotor gear box, which transmits torque to the tail rotor.

The cockpit controls include two throttles that enable the pilots to set the engines to a specific RPM. As long as the throttles are set in the proper range, engine power turbine speed (Nf) governing will maintain the selected RPM setting through the engine fuel control system. This system meters fuel through an elaborate hydro-mechanical system based on numerous inputs, to include Nf. With a given load on the drive system, if the Nf were set at 100 percent and the torque required to drive either the main rotor or tail rotor were reduced, the fuel control will reduce the fuel metered to the engine to maintain the set RPM. Likewise if the torque required increased, the fuel would have to be increased to keep the Nf from falling below the set RPM.

All properly operating helicopters have some degree of vibration. Vibrations change depending on various flight conditions such as RPM and load, and take on dynamic characteristics of frequency and amplitude. If a mathematical equation could be written to describe these characteristics, it would be called a "function." A function which causes a harmonic resonation in an object is referred to as the "forcing function."

4. SEQUENCE OF EVENTS

a. Mission.

On 7 Sept 2007, the 20 SOS was conducting a day/night single-ship training sortie in the vicinity of Hurlburt Field and the Eglin Range complex. The mishap aircraft, call sign Cowboy 21, was completing two qualification/instrument evaluations during the day portion, and low-level, NVG, infiltration/exfiltration training at LZ X-ray during the night portion of the flight. Cowboy 21 was planning to recover back to Hurlburt Field. This flight was authorized by the 20 SOS Assistant Director of Operations (ADO) (Tab K-5).

b. Planning.

The entire MC received adequate crew rest prior to showing for duty the day of the mishap (Tab V-1.24, 3.45-3.46, 5.13-5.14, 7.13, 8.19-8.20, 9.12-9.13). Mission planning was completed in accordance with (IAW) Air Force Tactics Techniques and Procedures (AFTTP) 3-3.34, Combat Aircraft Fundamentals MH-53M, dated 01 Apr 2007, Chapter 2, General Mission Preparation. The MCP planned this flight and was being evaluated for his First Pilot (FP) upgrade. He completed the planning using the Portable Flight Planning System (PFPS) which utilizes Falcon View and Combat Flight Planning System (CFPS). A mission operational risk assessment was completed by the MCP, briefed to the MC, and authorized by the 20 SOS/ADO (Tab K-11, K-12). Overall, the risk assessment was determined to be on the high side of low risk. Some individual items on the risk assessment were categorized as medium risk. Mission complexity (flight evaluations and number of planned mission events), moon illumination (0%), and BASH (bird avoidance strike hazard) conditions (moderate) were all categorized as medium risk (Tab K, 11-12).

c. Preflight.

A standard crew briefing was completed at approximately 1515 local time on 7 Sept 2007 in the 20 SOS building at Hurlburt Field, FL. The MCP briefed the MC IAW Air Force Instruction (AFI) 11-2MH-53V3CL-1, *Tactical and Non-tactical Aircrew Briefing Guide* dated 27 Apr 2005. All of the MC were present at the crew briefing with the exception of the MFS who was originally scheduled to fly with a different crew (Tab V-4.4). A briefing was completed for the MFS with respect to the training plan and mission details when he became part of the MC following a maintenance delay on his scheduled aircraft (Tab V-4.5). Local NOTAMs were checked and there was nothing significant to this flight (Tab T, 11-24). A standard local flight plan was filed at base operations that included instrument flight rules (IFR) routing to Pensacola Naval Air Station and Crestview airport (Tab K-3).

Takeoff was delayed by aircraft maintenance and weather. During run-up of the primary aircraft (tail number 1631), the MC received chip light indications in the cockpit. After two unsuccessful run-ups, the MC aborted their primary aircraft and proceeded to the MA (tail number 5794) (Tab V-1.4-1.5).

The MA was scheduled as the spare aircraft that night, so the MC "bumped" to the spare. Cowboy 23, another 20 SOS crew, was also experiencing maintenance problems with their primary aircraft and had already sent their flight engineers over to the spare aircraft to begin the pre-flight. When the MFEs arrived at the spare aircraft, the exterior and interior preflight was essentially complete. The priority for the spare aircraft was given to the MC, so the FEs from Cowboy 23 and the MFEs from the MC completed a face-to-face turnover briefing of the preflight inspection for the MA. The Evaluator FE was present during this standard briefing. This preflight was conducted IAW the Dash One and was not rushed (Tab V-1.4-1.5). The preflight FE stated all fluid levels were good and there were no leaks from the IGB or TGB (Tab V-10.4).

At the conclusion of the turnover, the MC delayed an additional 30-40 minutes due to weather. Once the weather had cleared, the MC completed a standard walk-around inspection of the MA to ensure there were no changes to fluid levels or cowling positions, and completed the aircraft run-up (Tab V-9.3).

During run-up of the MA, the Auxiliary Power Plant (APP) did not start initially. Once troubleshooting was complete, the APP started without incident and the remainder of the run-up was uneventful (Tab V-1.5). Takeoff was delayed 2 hours and 50 minutes due to the above mentioned maintenance and weather delays.

d. Flight.

Taxi and hover checks were completed without incident, and the engines were both operating properly. Initial takeoff was logged as 2205 local time and the MA flew 1.2 hours of contact maneuvers, emergency procedures, and instrument training at Hurlburt Field. During the first 1.2 hours of flight there were no events of consequence related to weather, maintenance, or general condition of the aircraft or crew. However, due to the maintenance and weather delays, the MC was unable to complete the MCP's scheduled evaluation. The MP re-prioritized the remaining training events given time available and decided to complete some low-level flight and alternate insertion extraction training at LZ X-ray. The evaluator FE was dropped off since the evaluation portion of the flight was complete for the night (Tab V-1.6).

Cowboy 21 departed Hurlburt Field at 2336 local time and completed a short low-level navigation route up the central corridor to LZ X-ray. This was uneventful except testimony from the MP that he felt a 6-per revolution vibration in the aircraft for two cycles of the rotor approximately 8 miles from the LZ (Tab V-1.7). This vibration only lasted a few seconds and was not significant enough to mention to the crew or terminate the mission (Tab V-1.7-1.8). Six-per vibrations are not uncommon.

Initially the MC planned on landing to the north into LZ X-ray. As the MA approached the LZ, the MC decided on an inbound heading of 090 degrees to minimize adverse effects of cultural lighting to their NVGs from the town of Crestview to the north (Tab V-1.7-1.8). The MC called Eglin Approach to report Cowboy 21 was established over LZ X-ray.

Cowboy 21 was flying at 100-150 feet above the highest obstacle (AHO). The approach, flown by the MCP, was planned to terminate in a 50 foot hover over the LZ, with a hoist recovery of a simulated team. Approximately 0.3 NM from the LZ, the MTS felt the onset of a 1-per revolution vibration which he did not consider significant enough to mention to the rest of the MC, and elected to continue the scheduled event (Tab V-5.8-9). The MCP attempted an approach to LZ X-ray and overshot the LZ by 1-2 rotors or 75-150 feet. While the MC was repositioning the MA, the MTS sensed the vibration was worsening and called a "go around" (Tab V-5.8, 5.9). (See Figure 1 for reference of events and aircraft ground track relative to the LZ.) The MTS stated the vibration was similar to a damper malfunction, but less severe. He has experienced two previous damper malfunctions, and has witnessed a third watching a formation partner fly with a damper malfunction (Tab V-5.11, 30).

The MTS had flown on this same aircraft on 28 August 2007 (Tab V-6.3). While acting as the tail scanner on this previous flight, the MTS recognized a high frequency vibration that was causing a "shudder" in the tail section of the aircraft. The crew air aborted and returned the aircraft to maintenance personnel for further analysis. The MTS stated that the vibration he felt on 28 Aug 2007 was completely different than the vibration he felt on the mishap flight and it had no impact on his decision to call a "go around" at the beginning of the mishap sequence (Tab V-6.2-6.6).

As the MCP began to transition to forward flight, the entire MC felt a vibration or a shudder in the aircraft (Tabs V-1.9, 3.11-3.12, 4.7-4.8, 5.4, 7.4, 8.7-8.8, 9.4). The MTS heard cyclical "zzzt, zzzt, zzzt" noises coming from the tail section and saw the tail pylon, using the extended tail skid as a reference, flexing downward approximately 9 inches at the same cadence as the noise (Tab V-5.8-5.10). The MFS reported a lateral vibration equal to 10% of left and right displacement of the aft fuselage which increased in magnitude as the mishap sequence developed (Tab V-4.23). The MP stated that initially he thought something was going wrong up in the rotor system, but that the symptoms were not like a damper failure (Tab V-1.16-1.17). The MP has experienced one prior damper failure (Tab V-2.11, 12).

All cockpit MC members reported fluctuations on the engine speed (Nf), rotor speed (Nr), and torque gauges (Tabs V-1.9, 3.14-3.15, 8.8). Throughout the mishap sequence the Nr/Nf readings fluctuated from 98-102%, 99-103%, 95-105%, 90-110%, and 80-120%. The MP took control of the MA and initiated a right turn to return to the LZ. The MCP remained on the controls with the MP for several seconds due to the severity of the situation (Tab V-3.34-3.35). The MP flew the pattern with the collective positioned for approximately 95-100% torque under normal operating conditions.

In an attempt to remedy the obvious problem, the MP, sensing a heaviness in the controls due to the fact the MCP was also still on the controls (Tab V-3.34-3.35), pushed the Automatic Flight Control System (AFCS) release button on his cyclic stick and announced it to the MC. Releasing the AFCS interrupts hydraulic pressure to the flight control servos to help isolate any flight control or hydraulic malfunction. When the MP realized the AFCS release did not remedy the problem, he directed the MFE to reset the AFCS (Tab V-1.11). The MFE finished restoring the system 25-30 seconds later when the MA was about 75-150 feet south of the LZ (Tab V-2.8-2.9). AFCS "off" throughout the approach may have masked some symptoms of the malfunction to certain crew positions.

Sensing the graveness of the situation, the MP made a "mayday" call, the first in his 4500-hour flying career (Tab V-2.27), to Eglin Approach (Tab V-1.9-1.10). Eglin approach queried, "Cowboy 21 say emergency" to which the MP replied, "Cowboy 21, LZ X-ray, we're landing" (Tab N-6). (See Figure 1 for timing references throughout pattern.)

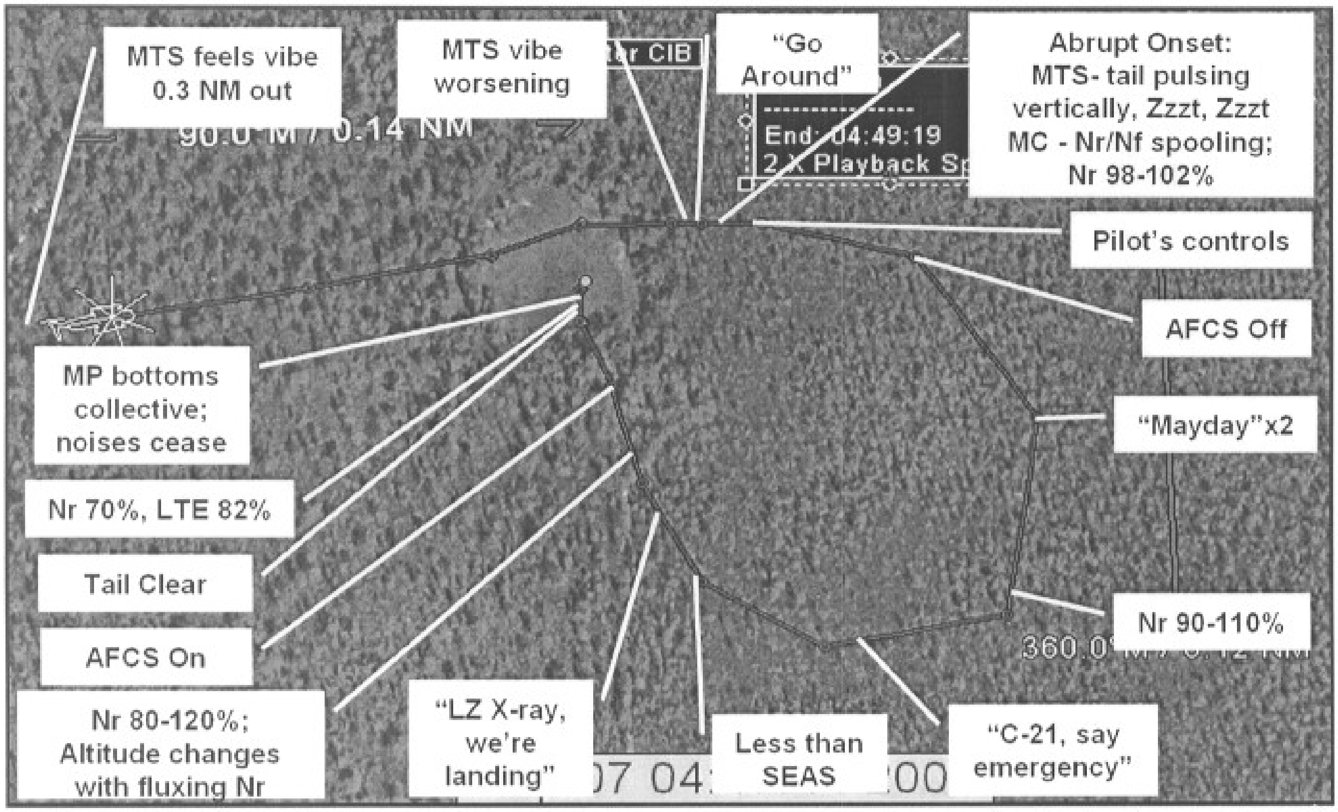

Figure 1 - MA ground track (based on mission computer data) and sequence of events (based on testimony and ATC data)

During the latter third of the approach, the MP's scan was focused on the triple tach (cockpit instrument with three needles which displays the rotor speed and the speed of both engines) and the outside environment. He does not recall specifically looking at the torque gauge, but recalls the needles fluctuating between approximately the 10:00 to 12:30 clock positions, corresponding to approximately 80-105% torque. This is equivalent to approximately 160 to 210% torque single engine. The single engine power available was less than 130% (Tab U-17). The MCP spent a good deal of his scan outside but does recall seeing a torque split of ten percent (Tab V-3.15). The MCP and MP stated that they could still read the instruments even though the instrumentation panel was vibrating (Tab V-2.20,3.55).

As the MLS, MRS, and MTS reported clear of the trees at the edge of the LZ, the MP noticed the rotor speed had decreased to 70% and was no longer fluctuating. The MFE, MP, MCP recall seeing 70% Nr (Tabs V-1.9-1.11, 3.14-3.17, 8.8). At 84 ft AGL the MP lowered the collective control stick to the bottom stop in an attempt to regain whatever rotor RPM he could, putting the MA in a rapid descent (Tab V-1.12). The MP's actions were prudent given the unique symptoms of the malfunction. In essence the MA was in an autorotative descent; however, the MP was not executing a specific emergency procedure and did not call for the throttles to be shut off (Tab V-

2.31). The MTS heard a "tunk", the "spooling" stopped, and he felt the aircraft descend (Tab V-5.5).

Mission computer data indicates that the mishap aircraft descended at an average rate of 1008 feet per minute in 5 seconds. At about 20-25 feet AGL, the MP pulled the collective to the upper stop to arrest the high rate of descent (Tab V-1.12). The main fuselage began a clockwise rotation or right yaw. A rotation of this nature can be caused by a loss of tail rotor effectiveness, which in this case would have occurred with the rotor speed below 82% (Tab J-53). It can also be caused by a loss of tail rotor drive due to a drive system malfunction. The MA sustained a hard landing in the southeast quadrant of the LZ.

The MA reached a maximum of 47 knots ground speed during the return route to the LZ. Single engine airspeed for the given conditions was approximately 26-31 knots indicated airspeed (Tab U-17). Based on mission computer data, the elapsed time from the onset of the malfunction until touchdown was approximately 45 seconds (Tab AA-2).

Crew resource management (CRM) was exceptional that evening, as noted by all crew members. (Tab V-1.22, 3.43, 4.8-4.9, 7.10, 8.14-8.17, 9.10-9.11)

e. Impact.

The MA landed at 2349 local time on 7 Sept 2007 at N30.67 4 W 086.59 13 at 112 feet MSL. Photographs show ground scars created by the left main, right main, and nose landing gear in the southeast portion of LZ X-ray. The left main landing gear touched first and the clockwise rotation of the aircraft caused the dirt to pile up in a northeastern direction. The right main gear touched next, and due to the rotation of the aircraft, the dirt piled up in a north-northwestern direction. The nose gear touched last, and the continued rotation of the aircraft caused the dirt to pile up in a southerly direction (Tab H-1-2, 11). All of the landing gear struts compressed to absorb the landing impact, but evidence only enabled an assessment of the right gear, which compressed approximately 11 inches (Tab H-5). The antennas and rotating beacon on the belly of the aircraft were undamaged (Tab H-4).

The MA touched down with a vertical velocity of approximately 570-780 feet per minute based on data from the mission computer and post-mishap calculations (Tab H-9). Mission Computer data and ground scar placement indicate that the MA touched down with little or no horizontal drift, and on a heading of approximately 115 degrees (Tab H-3). After initial touch down, the MA became airborne again and continued through at least 225 more degrees of rotation (Tab H-3). As the MA settled to the ground, it rolled as much as 70-75 degrees on its left side causing the main rotor blades to impact the ground (Tab H-4).

The tail section fractured on the right side of the fuselage at the ramp hinge, station 522, due to the initial impact, but remained partially attached to the MA throughout the entire rotation. The tail rotor drive shaft cowling over the #3 drive shaft separated from the MA and fell on top of the ground scar left by the tail skid (Tab H-4). The #3 drive shaft coupling to the #2 drive shaft failed, and the drive to the tail rotor ceased (Tab U-11.4). The tail rotor decelerated and stopped rotating before it contacted the ground (Tab H-4). The auxiliary fuel tank provided stability that kept the MA from rolling completely on its left side. The tail section rotated 115 degrees to the left of the main fuselage and settled on the ground with the tail rotor blades lying on and parallel to the ground (Tab H-4). The main fuselage came back to rest on the right, nose, and collapsed left main landing gear, and all violent motion ceased (Tab H-4). Impact was attenuated through the compression of the earth, tires, and stroking of the gear, resulting in a lateral load of 1-2 gravitational forces (Gs) and vertical load of approximately 0.8-1.1 Gs. The MP recalls an inbound heading of 340 to 360 (Tab V-1.18).

f. Life Support Equipment, Egress and Survival.

During the initial phases of the mishap sequence, the MFS lay down on the troop seat that was set-up on the left side of the rear cabin area. Once the MA was clear of the tree line, the MTS also moved forward of the ramp hinge and lay on the cabin floor. After landing and during the violent motion that ensued, the MTS and MFS were ejected from the MA and were dragged behind the MA as it spun. They remained tethered to the MA by their gunner's belts, which remained attached to the inside cabin.

When the MA settled and all motion ceased, the MTS was on the ground directly behind the MA. The MFS was on the left side of the MA inside the "L" formed by the main fuselage and the now broken tail section. (Tab V-4.8-4.10). The MP immediately noticed the smell of jet fuel. He initiated the egress sequence by stating "egress, egress, egress" over the intercom and also loud enough for the rest of the MC to hear. The MCP pulled the emergency release handle on his cockpit window and egressed through the left window (Tab V-1.13).

Because of his pre-landing position and relatively short distance from the point of rotation, the MLS was able to maintain a crouched position between the left window and the electronics rack on the left side of the cabin; he unhooked his gunner's belt and egressed through the tail opening (Tab V-9.9). The MRS had time to bring the hoist and forest penetrator up, but not to get it in the door. He left the penetrator hanging outside the door and laid down on the cabin floor for the anticipated hard landing. After the motion of the MA had ceased, the MRS was located under the left gun on the left side of the MA. The MRS unhooked his gunner's belt normally and egressed through the tail opening (Tab V-7.5).

The MFE unbuckled his seat restraint, folded up his seat, and egressed through the tail opening. The MP followed the MFE through the cabin and out the tail opening. As the MP was climbing out of the cockpit, he noticed the throttles and fuel control levers were still in the full forward position. There was no engine noise, but the MP decided to pull the throttles and fuel control levers to the "off" position during his egress (Tab V-1.13-1.14). All members, except the MLS, lost their NVGs during the mishap sequence (Tab V-9.9). The MFE was the only crewmember who had not been wearing NVGs as is customary for his crew position (Tab V-8.9).

Within a matter of minutes, the MC joined up at a position directly behind the MA. They assessed all injuries and then decided to move to a safer position away from the MA. Despite his back injury during the crash, the MFS examined the MTS's leg and then awaited rescue personnel (Tab V-4.11, V-4.13).

The MP and MCP contacted the Hurlburt command post via cell phone. The MCP contacted Spur 62, an AC-130H, at 2355 local time using his PRC-112 survival radio, which was returning to Hurlburt Field from a training sortie. Spur 62 acted as on scene commander and communications relay until other rescue assets arrived (Tab V-4.13, 16).

There were no noted deficiencies in life support or survival equipment (Tab H-8-12).

g. Search and Rescue.

The first emergency medical helicopter landed at 0105 local time. The first emergency medical helicopter departed LZ X-ray at 0133 local time and landed at the Baptist Medical Center in Pensacola, FL at 0157 local time. The second helicopter landed at LZ X-ray at 0107 local time and departed at 0141 local time, and landed at Sacred Heart Surgical Center, Pensacola, FL at 0200 local time. The MFS and MTS were treated and released the following day. Ground support crews (firemen and local police) were on scene by 0015 local time. The remainder of the MC was ground evacuated to Eglin AFB Hospital, treated for minor injuries, and released that night. The rescue effort was executed with little or no delay and in an exceptional manner.

h. Recovery of Remains.

Not Applicable

5. MAINTENANCE

a. Forms Documentation.

Air Force aircraft maintenance and inspection histories are documented on the Air Force Technical Order (AFTO) 781 series forms and in a computer database known as the Core Automated Maintenance System (CAMS). In addition to scheduling and documenting routine maintenance actions, these tools allow aircrew to report aircraft discrepancies and for maintenance personnel to document the actions taken to resolve them. Additionally, they provide a tool to research past aircraft problems to more effectively troubleshoot and solve new maintenance discrepancies.

Time Compliance Technical Orders (TCTO) are system changes, usually parts upgrades, which must be completed by a specific date. A TCTO may also direct inspections or adjustments to equipment or parts already installed on the aircraft or ground support items. TCTOs may be immediate, urgent, or routine based on the severity of the issue. Time change items are routine maintenance actions in which components are removed and replaced for overhaul at a given number of flight hours.

The AFTO Forms 781 consist of aircrew and maintenance documentation to include flight data, maintenance discrepancies, flight status, aircraft and engine operating time, and calendar inspections. A review of the CAMS data and a 90-day review of the MA AFTO Forms 781 found no discrepancies related to the mishap. All AFTO Forms 781 on board the MA at the time of the mishap were recovered and are contained in Tab D, pages 5 to 33.

There were no overdue TCTOs, time change items, or special inspections at the time of the mishap. The MA's maintenance preflight was signed off at 0200 local time, 7 Sep 07 and was valid for 72 hours (Tab D-7). The MA forms were transcribed after the maintenance pre-flight. There were no grounding discrepancies open and no open discrepancies affecting the air worthiness of the MA. The transcribed and archived forms were in good order with minor documentation errors not related to the mishap. TCTO 1H-53-953, *Replacement of Intermediate Gear Box*, with a ground date of 1 June 2009 was open in the forms (Tab D-23). The TCTO was released to correct internal deficiencies and to increase compatibility between Air Force and Navy H-53 variants (Tab U-10-16). A TCTO kit was available, but the aircraft was scheduled for transfer to the Aerospace Maintenance and Regeneration Center (AMARC) in October 2007 to be retired (Tab U-20). A management decision was made to not install a new gearbox due to the fact the TCTO ground date was 20 months away, unless, of course, the gear box encountered a problem requiring replacement.

b. Inspections.

Inspections on the MA were up to date and correct. A combat phase inspection was accomplished 5 Mar 07 at a deployed location. A combat phase is a set of inspections that may be authorized for use by the MAJCOM in lieu of normal phase inspections during contingency operations. The inspection may be substituted for either the A or B phase inspection and consists of both the A and B phase inspection critical elements. Once a combat phase is accomplished in lieu of the normal phase inspection, the next sequential phase inspection is performed as regularly scheduled. The MH-53 is required to have an A phase inspection every 300 hours and a B phase inspection every 600 hours (Tab D-3, 21). When it departed for the mishap mission, the MA had 189.9 flight hours since the combat phase inspection. A main rotor head damper bearing inspection was accomplished prior to takeoff and resulted in inboard bearing changes on the blue, red, black, and yellow blade dampers. Additionally, a tail rotor head pitch link inspection was accomplished at the same time with no defects (Tab D-5, 21).

c. Maintenance Procedures.

The MA had experienced a tail rotor vibration shortly after departure on 28 Aug 07. The crew returned to base and maintenance personnel performed a tail balance check and found a vibration of 0.17 inches per second, which was over the standard of 0.1 inches per second. Maintenance personnel performed a tail balance and launched the MA again (Tab U-2.7). The vibration persisted and the crew returned to base. The tail rotor pitch links and tail rotor damper bearings were inspected and no defects were found (Tab U-2.8). The MA was scheduled for an operational check flight (OCF) the following day. On 29 August, an ARINC crew flew the MA and signed off the OCF with no defects noted (Tab U-2.9). ARINC is a government contractor that performs OCF and Functional Check Flight (FCF) services for MH-53 aircraft at Hurlburt Field. The MA subsequently flew once on 4 Sep 07 and once on 6 Sep 07 with no issues related to the mishap. (Tab D-20)

d. Maintenance Personnel and Supervision.

The training records and special certification rosters all indicated proper maintenance discipline with respect to pre-flight, servicing, and maintenance procedures. The records for maintenance personnel who had interacted with the MA in the 14 days prior to the mishap flight had some minor documentation errors, but none were related to the mishap (Tab G-77).

e. Fuel, Hydraulic and Oil Inspection Analysis.

Fuel, hydraulic, and oil samples were tested from all fuel tanks, all gear boxes, hydraulic systems, and three hydraulic servicing carts. Additionally, the fuel truck and fill stand used to fill the truck were sampled. All samples were found to be within Air Force standards (Tab D-37, TAB O-7 through 23).

f. Unscheduled Maintenance.

Unscheduled maintenance performed on the MA prior to takeoff included three Forward Looking Infrared (FLIR) discrepancies, replacement of four rotor blade damper bearings, and rebonding of a main rotor anti-flap restrainer. All discrepancies were signed off IAW applicable TO's 7 Sep 07 (Tab D-5). Additionally, the IGB was serviced by an L3 COM contract employee on 23 August 2007. A review of the associated AFTO Form 781A indicated proper servicing procedures IAW technical orders. No leaks or abnormalities were noted at the time of servicing (Tab U-6).

The MA had 12,184.4 hours, excluding the final 1.6 hours flown (Tab D-5). It had been converted to an MH-53J in Mar 1989, (Tab U-7.2) and completed the USAF Service Life Extension Program (SLEP) Dec 1992 during which the transition section was replaced with a 68-model aircraft. The landing gear was replaced, and the MA was fitted with the 50K landing gear, structural improvement, and modified aft fuselage structure (Tab U-7.1). The MA received the USAF-designed crashworthy fuel system modification in March 1996 and the MH-53M modification in October 1998 (Tab J-20). The IGB was installed on the MA on 6 Jun 2005 and had accumulated 963.7 flight hours prior to the mishap flight. When it was mounted, the IGB had zero flight hours since its last overhaul (Tab U-7.3).

6. AIRCRAFT AND AIRFRAME, MISSILE, OR SPACE VEHICLE SYSTEMS

a. Condition of Systems.

The MA came to rest in the southeast portion of LZ X-ray approximately 5 miles south of the town of Crestview, Florida, and approximately 4 miles west of Duke Field. LZ X-ray is an oval-shaped clearing roughly 180 feet long by 212 feet wide. It is surrounded by trees that are approximately 50-60 ft tall. The surface can be boggy during and after a rain storm (Tab H-6, O-3), but was dry on the night of the mishap. Debris from the MA was found several hundred feet in all directions from the main fuselage. Several main rotor blade pieces were found in all directions (Tab S-3-7). The cockpit and forward cabin were essentially undamaged and sitting upright (Tab S-11). The voice warning system was found in the "off" position and was off the entire flight (Tab V-2.2). The in-flight refueling probe and FLIR were undamaged (Tab S-11). The TF/TA Radar radome was crushed on the left side (Tab S-12). The bottom of the MA never touched the ground as all antennas on the lower fuselage were intact (Tab H-4).

The left auxiliary fuel tank, sponson, and main landing gear sustained crush damage associated with a left roll of 70-75 degrees. Approximately 1000 lbs of fuel leaked out of the left auxiliary tank (Tab J-19). All sections of the tail (transition section, tail cone, and tail pylon) were torn away from the main fuselage at the ramp hinge, and came to rest on the ground at approximately a 115 degree angle to the main fuselage (Tab J-6). Wire bundles, hydraulic lines, and a small amount of aluminum skin were all that kept the tail connected to the main fuselage. Just forward of the ramp hinge, the main cabin ceiling was caved in and the drive system was broken at the forward end of the #3 drive shaft. All remaining drive shafts were intact. The cargo ramp separated at the hinges and was lying upside down approximately 30 feet behind the main fuselage. The tail skid was basically undamaged and in the fully extended position. Ground scars indicate it was dragged across the ground for about 45 degrees of clockwise rotation. Some build-up of dirt and grass was evident in the left side of the tail skid plate (Tab J-5-10).

The main rotor head was still in place; however there was excessive damage to the dampers, pitch links, pitch change rods, and other mechanical parts. All damage to the main rotor head can be attributed to the main rotor blades striking the ground. Ground scars at the 8:30 to 10:30 clock positions indicate that the main rotor blades struck the ground on the left side of the final resting position of the main fuselage (Tab J-7).

Both main fuel tanks and the right auxiliary fuel tank were undamaged and the fuel gauges read as follows; Right aux 1080 lbs, Right main 1800 lbs, and left main 1800 lbs (Tab J-27).

The tail section was basically intact, despite the fact it was separated from the main fuselage at station 522 and lying on the ground. The tail gearbox was still attached and in it's original position. Inspectors discovered damage to the internal teeth during post-crash teardown inspections (Tab J-12).

The intermediate gear box (IGB) was still attached and in its original position. However, it was loose in its mount and there was damage to the mounting studs, the gear box casing, and all the internal gear teeth (Tab J-9-11).

Two of the tail rotor blades exhibited flatwise bends, consistent with low energy and near zero RPM impact with the ground near the end of the mishap sequence. The two remaining tail rotor blades showed no sign of damage. All pitch change links and the pitch change beam remained attached. All four spindles remained intact however the blade fold positioner crown was fractured in an apparent static overload from ground impact (Tab J-12-13).

Both engines were removed and sent to Cherry Point for analysis. See "Testing" below for details.

b. Testing.

Testing was conducted on the MA engines and related components, as well as the MA drive train, to include the main rotor and associated components, tail rotor, and associated components, all seven drive shafts, and the intermediate and tail gear boxes. Detailed analysis is found in TAB J.

Both MA engines, General Electric S/Ns 00261048 (#1 Position) and 00261008 (#2 Position) were removed along with their associated engine components and transferred to Navy Depot (NADEP) Cherry Point for analysis. Both engines were visually inspected for foreign object damage (FOD), impact damage, and the possibility of engine failure. The #2 engine exhibited 1st stage gas generator turbine rub marks by the turbine blades on the turbine shroud visible from 4 o'clock to 7 o'clock position when viewed from the aft portion of the engine (Tab J-80). These marks are a typical result of an engine sustaining a sudden impact. Additionally, the engine was placed on a test stand and motored to 5,000 RPM (normal operating speed is over 13,000 RPM). It was allowed to spin down to 2,000 RPM where it began vibrating on the stand. This vibration was not out of TO limits when installed on an aircraft, but was not normal for test stand operation. Testing was halted to prevent any more damage to the engine, personnel, or testing facility (Tab J-80).

The #1 engine was placed on the test cell and inspected. Functional checks were normal, and a full performance run was initiated on the engine. The engine functioned normally, producing 4490 shaft horsepower, 130 shaft horsepower more than required specifications of 4360 shaft horse power (Tab J-81, U-6.1).

Both engines were boroscoped and showed normal signs of wear commensurate with their current operating time and environment. Additionally, fuel control and filter bowls were checked with no abnormal results (Tab J-80-81).

The MA drive train and both rotor systems were removed and shipped to Sikorsky for teardown analysis. Detailed results are contained in Tab J and Tab U. The main gear box was observed to function normally when input and output shafts were spun. There were no instances of binding or other abnormalities when spun by hand (Tab U-11.4). The main rotor system exhibited damage to major components consistent with rotor blades impacting the ground as a result of the mishap sequence (Tab U-11.4, Tab J-7-8). The MA tail rotor drive shafts were damaged to varying degrees, but also consistent with crash damage (Tab U-11.4, Tab J-8-9).

The IGB center housing was separated at the input housing casing mating surface. Eight mounting studs normally hold the input housing to the center housing. Visual inspection revealed one stud intact with a nut installed. The other seven mounting studs exhibited stripped threads, broken stud, stud pulled from their mounting holes, or a combination thereof. (See Figure 2 for positional reference on mounting studs and nuts.) Additionally, there were cracks found at the mounting stud holes at the #1 and #5 positions. The studs had been pulled from the mounting holes at these positions (Tab J-11). The final assessment indicated the housing had cracked and separated prior to removal of the #1 stud (Tab U-11.1). However, the threads in the #5 stud hole were stripped in the housing where the stud had pulled partially out (Tab U-11.1). The IGB mounting studs are attached to the center casing using a threaded insert drilled into the casing itself. The studs are then screwed into this insert, and the IGB is mounted to the aircraft and secured by nuts on the mounting studs. Additionally, assessment of the input and output gear heads on the IGB revealed impact damage to both gear assemblies. The IGB output shaft gear assembly was noted to have intermittent impact damage around the circumference of the assembly. NDI inspection revealed cracks over 75% of the gear tooth root area (Tab U-4.2).

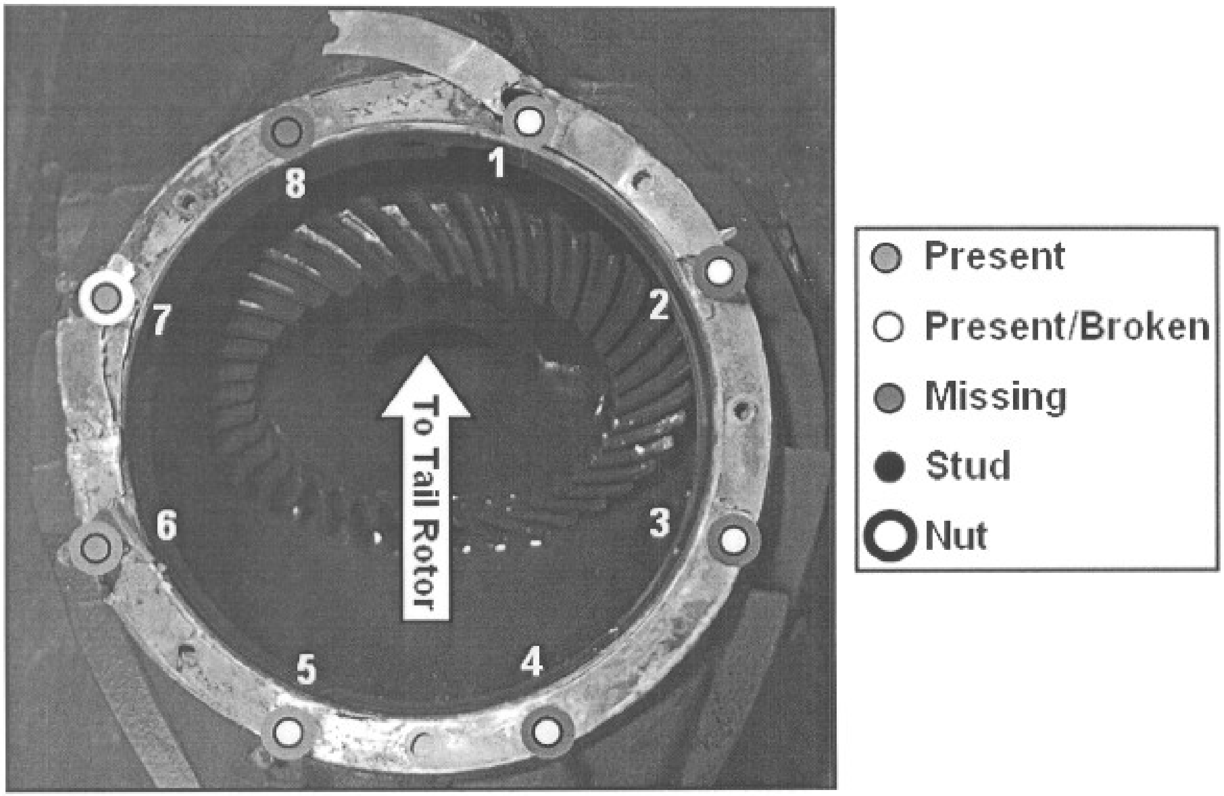

Figure 2 - IGB Center Housing as viewed from front to back of aircraft

At the time of the mishap, torque values for IGB mounting studs in the approved AFTO's were different than those in the current technical drawings from Sikorsky. The AFTO specified a torque value of 200 inch pounds (Tab U-2.3-4) as opposed to 140-145 inch pounds stated in Sikorsky IGB technical drawings from 2004 (Tab U-17). Historical drawings from 1968 supplied by Sikorsky Aircraft Corp. did not specify a torque value, but identified an MS21042-5 nut as attaching hardware to the IGB (Tab U-10.6). In 1976, Sikorsky Engineering Order 41242 (Tab U-10.4) changed that hardware specification to an SS5086-05 nut, and established a torque value of 140-145 inch pounds. The hardware and torque value changes were included in the 1984 updated assembly drawings for the transmission pylon (Tab U-10.8) and again in the 2004 engineering drawings (Tab U-10.9). The AIB was unable to determine why Air Force technical data did not match the Sikorsky drawings or if a cohesive system was in place at the time to update users on drawing changes.

The change to the drawings was documented as a Class II change. Class II changes are normally administrative in nature, and are typically reviewed by a local government representative (Tab U-19), but do not meet the scrutiny of a configuration control board, and thus would not be reviewed by the AF for inclusion in the AFTOs. However, this change was not just administrative in nature. By today's standards, this change would have been listed as a Class I change and would have met a configuration control board to evaluate and approve the change, and incorporate it into applicable tech data, if required. (Tab U-11.3). A government representative reviewed and signed the 1976 engineering order on June 1, 1976 (Tab U-10.4), but there is no evidence to determine what was or was not provided to the USAF.

The USAF did not have the current engineering drawings for mounting the IGB in the electronic drawing management system, the Joint Engineering Data Management Information and Control System. The drawing on file in the USAF system was dated 1971 (Tab U-18). After the published engineering change in 1976, the earliest engineering drawing reflecting the updated torque value was produced in 1984, 23 years prior to the mishap (Tab U-12.12). The current engineering drawing is dated 2004, 3 years prior to the mishap (Tab U-2.17). There was no contract mechanism in place to ensure new engineering drawings were entered into the electronic drawing management system for Air Force MH-53 Helicopters when the current drawings were published in 2004 (Tab U-11.3). The board was unable to determine the process in place in 1984 and earlier.

Following the mishap, a TCTO was issued 19 Oct 07 to inspect all MH-53s and adjust IGB torque values to that prescribed by Sikorsky drawings (Tab U-2.19-21 through 21). Additionally, a technical order revision was released on 19 Oct 07 to correct AFTO's for removal and replacement of the IGB and add the proper torque values on the mounting studs and hardware (Tab U-2.23-24).

c. Other Analysis.

Several experts were contacted in an effort to duplicate the Nf oscillation phenomena encountered by the crew during the mishap sequence.

An engineer at NADEP Cherry Point was contacted to see if the MA engines could be run on a test cell under conditions similar to the mishap sequence; they could not. However NADEP did release a message which explained characteristics of the fuel metering and how it could lead to diverging engine oscillations given certain cyclic, abnormal inputs. The message stated, "…if the cyclic input is at a frequency not associated with the design of the governor, the governor and hence the engine rotating system may not react with precision to offer a steady Nf and may in fact diverge." (Tab U-13.5)

The Professor of Aerospace Engineering, Department of Aeronautics and Astronautics, Air Force Institute of Technology (AFIT) indicated that the accident scenario reported to him by the AIB President, though seemingly a bit unlikely, is not impossible. His analysis was admittedly speculative; lacking knowledge of the T-64-100 engine system time constants, i.e., times for responses to internal/external loading inputs. He does not have any intimate knowledge of the systems particular to the MH-53M helicopter nor of the system dynamic responses integrated with the fuel control system of the GE T-64 engines, so he could not suggest any one system was at fault. However, in his opinion, the situations described are theoretically possible (Tab U-3.2).

The T64 Engine Component Improvement Program (CIP) Engineering Status Report, 2 Dec 1976 to 5 May 1977, summarized a phenomenon that surfaced during CH-53E tests by Sikorsky in 1976-77 and is nearly identical to what occurred with the MA. The test pilots encountered diverging Nf oscillations on the T64-GE-415 engine, which had been successfully used for years on the CH-53D, a 2-engine, 6-blade helicopter. The CH-53E is a 3-engine, 7-blade helicopter. Helicopter rotor blades are essentially on a hinge, and as each blade rotates, it will flap up and down and lead and lag. As a blade leads and lags, it induces minor, unperceivable rotor speed changes, similar to those experienced by the MA. The initially unperceivable speed changes became apparent as the oscillation diverged. The CIP revealed that the lead-lag dampening characteristics of the 7-blade rotor head on the CH-53E induced an engine speed change at a 2 Hz input and subsequent diverging Nf oscillation. The problem was resolved with a relatively simple modification. (Tab U-6.9, U-9.1-2). The Nf phenomenon which occurred during the testing of the CH-53E was essentially the same as what was encountered on the MA, except the forcing function in 1976-77 was induced by the lead-lag characteristics of the 7-blade rotor.

Vibration Monitoring System (VMS) data was downloaded via data card and analyzed for possible vibrations on the mishap flight. The VMS system consists of multiple sensors placed at various points in the aircraft to monitor vibrations (Tab L-23-45). Analysis conducted by on-site VMS program managers from Rhino Corporation did not reveal any data indicating abnormal vibration. VMS is a trending tool and takes instant readings every four minutes, and did not capture any abnormal data during the mishap flight. The time is based on the elapsed time of the flight starting when the main rotor reached 70% Nr. The VMS time is not linked to the aircraft mission computer. The VMS gets its clock time from laptops used to download the data from the aircraft. Six laptops were checked to compare clock times and produced six time hacks up to seven minutes apart. When the VMS weight on wheels (WOW) data was compared to the mission computer time clock, the board was able to determine the mishap vibrations would not likely have been recorded by the VMS.

7. WEATHER

a. Forecast Weather.

Takeoff weather was forecast as scattered clouds at 3000, scattered clouds at 15,000, and scattered clouds at 25,000 with visibility greater than seven miles. Winds were forecast for 150 degrees at 10 knots. Temperature was to be 30 degrees Celsius, with an altimeter setting of 3006 inches of mercury. Pressure altitude was forecast to be -89 feet, and there were no forecast hazards (thunderstorms, turbulence, icing, precipitation). Sunset was forecast to occur at 1901 local time, and end effective nautical twilight (EENT) to occur at 1954 local time. Moonrise was not to occur until after landing (0230 local time), and illumination would have been 18% when the moon rose (Tab F).

Recovery weather was forecast to be scattered clouds at 3000 feet, scattered clouds at 25,000 feet, and visibility greater than 7 miles. Winds were forecast to be 070 degrees at 5 knots, and the altimeter setting was to be 3008 inches of mercury. Pressure altitude was forecast to be -108 feet (Tab F).

b. Observed Weather.

Weather at the time of the mishap was reported by Duke Field as sky clear with visibility greater than 10 miles. Winds were 3 knots at 050 degrees, and the altimeter setting was 3007 inches of mercury. The Hurlburt Field meteorological aviation report (METAR) for the mishap time indicated sky clear, visibility greater than 10 miles, winds were 3 knots at 010 degrees, and the altimeter setting was 3005 inches of mercury. Temperature was 26 degrees Celsius, dew point was 23 degrees Celsius. Night prevailed with 0 percent illumination from the moon. The moon phase was a waning crescent, with 18% visible disk illumination, but had not risen at the time of the mishap (Tab F). The MP estimated the effective illumination to be 7% due to starlight and as much as 30% due to cultural lighting from Crestview (Tab V-1.19).

c. Space Environment.

Not applicable.

d. Conclusions.

The MC conducted operations in accordance with published instructions and within prescribed operational weather limitations.

8. CREW QUALIFICATIONS

a. Mishap Pilot.

The MP completed the HH-1H Initial Copilot qualification at Detachment 3, 37 ARS, Grand Forks AFB, ND on 6 Dec 1991 and Initial Aircraft Commander (AC) on 28 Sept 1992. He completed his HH-1H Initial Instructor Pilot (IP) qualification on 30 Sept 1993.

On 18 Jul 1995, he received his Initial Qualification in the TH-53A at the 551 SOS, Kirtland AFB, NM and attained the required hours to upgrade to First Pilot (FP) in the MH-53J on 2 Aug 1996 at the 20 SOS, Hurlburt Field, FL. On 22 Jan 1997, he completed his Mission Pilot qualification at the 20 SOS and his Initial Night Water Operations (NWO) Qualification on 19 Aug 1997. The MP completed his Initial Mission IP Qualification on 15 Dec 1997 at the 20 SOS and then was reassigned to the 58 OSS/551 SOS, Kirtland AFB, NM as an MH-53J IP. He upgraded to MH-53J Evaluator Pilot (EP) on 2 Jun 2001. On 16 Sept 2003, the MP returned to Hurlburt Field, FL and maintained his IP/EP qualifications. He then went to a non-flying staff assignment, but returned to the 20 SOS, Hurlburt Field, FL and re-qualified as an IP on 24 Jul 2007.

Throughout his training, the MP maintained noteworthy procedural knowledge, exceptional situational awareness, and commendable crew coordination. It was also noted he consistently flew all maneuvers in an excellent and outstanding manner. No discrepancies were noted during his most recent re-qualification. He had 4508.3 total hours and 2523.5 hours in the MH53J/M at the time of the Mishap. On the night of the mishap, he was current in all flying and ground training events (Tab G-4)

Recent flight time (Tab G-1.1)

b. Mishap Co-Pilot.

The MCP completed the UH-1N Initial Qualification on 19 Sept 2001 and his Initial Mission Qualification on 29 Nov 2001 at the 512 RQS, Kirtland AFB, NM. On 17 Jun 2002 he completed his Initial Mission Qualification at the 1 Helicopter Squadron, Andrews AFB, MD. He returned to the 512 RQS and completed his UH-1N AC upgrade on 21 Mar 2003. On 31 Jan 2004, the MCP received his UH-1N Initial IP upgrade at Kirtland AFB, NM. He then transitioned to the MH-53J and completed his Initial Qualification on 17 Jun 2005 and his Initial Mission Qualification on 19 Jan 2006 at the 551 SOS, Kirtland AFB, NM. On the night of the mishap, the MCP was accomplishing his FP and annual Qual / Instrument evaluation.

The MCP successfully completed all training flights in a satisfactory or exceptional manner. He had 1456.9 total hours and 500.3 hours in the MH53J/M at the time of the Mishap. On the night of the mishap, he was current in all flying and ground training events except Pubs Check, FCF Exam Open Book, Pave Low Coupled Approach, and Alternate Insertion/Extraction. The night of the mishap, he had an instructor pilot (IP) on board in order to get recurrent on the coupled approach and AIE's. The Pubs Check was completed as part of the Qual/Instrument Evaluation (Tab G-4).

Recent flight time (Tab G-1.2)

c. Mishap Flight Engineer.

The MFE completed the MH-53J/M Initial Flight Engineer Qualification on 20 Nov 2006 and the Initial Mission Qualification on 20 Mar 2007 at the 551 SOS, Kirtland AFB, NM. He received a Q-3 for Initial Mini Gun Qualification, but received a Q-1 on the re-evaluation on 28 Mar 2007. On 15 Aug 2007, the MFE completed his Initial Mission Low Visibility Approach

(LVA) qualification at the 20 SOS, Hurlburt Field, FL in the MH-53M. On the night of the mishap, he successfully completed his recurring Qual evaluation without discrepancies.

The MFE successfully completed all training flights in a satisfactory manner. His training folder contained comments consistent with an initial qualification student. He had 173.3 total hours and 173.3 hours in the MH53J/M at the time of the Mishap. On the night of the mishap, he was current in all flying and ground training events (Tab G-4).

Recent flight time (Tab G-1.3)

d. **Mishap Right Scanner.**

The MRS completed the MH-53J Initial Flight Engineer Qualification on 17 Nov 2005 and the Initial Mission Qualification on 10 Aug 2006 at the 551 SOS, Kirtland AFB, NM. On 19 Nov 2006, the MRS completed his MH-53M recurring qualification evaluation at the 20 SOS, Hurlburt Field, FL. On 7 Mar 2007, he accomplished his Mission and Initial Mission Low Visibility Approach (LVA) Evaluations.

The MRS successfully completed all training flights in a satisfactory manner. He had 336.4 total hours and 336.4 hours in the MH53J/M at the time of the Mishap. On the night of the mishap, he was current in all flying and ground training events (Tab G-4)

Recent flight time (Tab G-1.4)

e. Mishap Left Scanner.

The MLS completed the MH-53J/M Initial Gunner Qualification on 13 Mar 2002 at the 551 SOS, Kirtland AFB, NM. On 27 May 2003, the MLS completed his MH-53M Initial Mission Qualification at the 21 SOS, RAF Mildenhall, UK. On 10 Mar 2005, he successfully accomplished his recurring Mission evaluation and Initial Instructor Gunner (IG) qualification at the 551 SOS, Kirtland AFB, NM on the MH-53J. His most recent Mission evaluation was completed at the 20 SOS, Hurlburt Field, FL on 7 Mar 2007.

The MLS successfully completed all training flights in a satisfactory manner. He had 1542.0 total hours and 1538.1 hours in the MH53J/M at the time of the mishap. On the night of the mishap, he was current in all flying and ground training events (Tab G-4).

Recent flight time (Tab G-1.5)

f. Mishap Tail Scanner.

The MTS completed the MH-53J/M Initial Gunner Qualification on 14 Nov 2006 at the 551 SOS, Kirtland AFB, NM. On 31 May 2007, the MTS completed his MH-53M Initial Mission qualification at the 20 SOS, Hurlburt Field, FL.

The MTS successfully completed all training flights in a satisfactory manner. He is a very new crewmember and his training folder contained common trends for initial qualification students. He successfully completed all evaluations without any discrepancies. He had 239.6 total hours and 239.6 hours in the MH53J/M at the time of the Mishap. On the night of the mishap, he was current in all flying and ground training events (Tab G-4)

Recent flight time (Tab G-1.6)

Name (Duty Position)	Crew Qual	30 Days	60 Days	90 Days	Total Time	MH-53 Time
Lt Col Eugene V. Becker (EP)	EP	16.5	45.7	51.7	4508.3	2563.5
Maj Scott T. Yeatman (MC)	MC	4.0	16.2	45.8	1456.9	500.3
A1C Evan R. Pinkerton (MF)	MF	38.1	64.3	76.7	173.3	173.3
SrA Joshua K. Plant (MF)	MF	0.0	12.0	38.8	336.4	336.4
SSgt William J. Sell (MG)	IG	16.8	35.4	57.9	1542.0	1538.1
A1C Bradley T. Jordan (MG)	MG	39.4	83.7	92.3	239.6	239.6
Col William E. Nelson (FS)	FS	0.7	5.2	5.2	626.1	209.0

9. MEDICAL

The injuries sustained from the MA included moderate injuries to the MFS, who was seated in the left aft tail section, and the MTS. Both the MFS and MTS were ejected from the rear of the MA during the mishap landing, but remained tethered to the aircraft by their gunner's belts. Minor injuries were sustained to the MCP, MFE, MRS, and MLS. The MP developed mild musculoskeletal pain the day after the mishap. There was no evidence that medical qualifications, toxicology, lifestyle, or crew rest directly contributed to this mishap.

a. Qualifications.

All MC were medically qualified for flight at the time of the accident. All annual flight physicals were current with appropriate documentation. The medical record of the MFS was missing a signed copy of his most recent annual flight physical AF Form 1042. All other documents were posted in the medical record or found in the electronic medical record.

b. Health.

There were no health concerns or recent medical conditions of note in any of the MC records prior to the mishap event. The following chart lists the date of each member's last physical, post mishap injuries and date they were returned to flight status.

Crew Position	Annual PHA	Post Mishap injuries	Post crash Return to flying status
MP	18 Apr 07	Back pain	14 Sept 07
MCP	15 May 06 (current)	Back pain	20 Sept 07
MFE	18 Oct 05 (current)	Back pain, ankle sprain, bruising and abrasion, shoulder strain	24 Sept 07
MRS	13 Feb 07	Back pain, hip pain, shoulder pain, ankle sprain	2 Oct 07
MLS	13 Mar 07	Back Pain	21 Sept 07
MTS	30 Apr 07	Fractured leg, ligament tear, concussion, neck strain, multiple abrasions and contusions	DNIF as of 15 Oct 07
MFS	30 Aug 07	Fuel fume inhalation, shoulder contusion, back pain, multiple abrasions	9 Oct 07

c. Toxicology.

The Armed Forces Institute of Pathology conducted toxicology screening for all seven MC and eight maintenance personnel. The blood was screened for carbon monoxide and ethanol. The urine was screened for amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opiates and phencyclidine. All results were negative.

d. Lifestyle.

There is no evidence that unusual habits, behavior, or stress on the part of any of the MC contributed to this accident.

e. Crew Rest and Crew Duty Time.

Evidence indicates the MC had adequate pre-mission rest in accordance with Air Force instructions. AFI 11-202, Volume 3 stipulates Air Force Crew members require at least 8 hours of continuous, uninterrupted rest during the 12 hours immediately prior to the beginning of the flight duty period. Rest is defined as the condition that allows an individual the opportunity to sleep.

Crew Position	Time/date departed work	Time arrived work on mishap day/ off duty hours	Sleep during prior 12 hours
MP	0100/ 7 Sept 07	1400/ 13 hours	8+30 hours
MCP	1800/ 6 Sept 07	1300/ 19 hours	10 hours
MFE	1630/ 6 Sept 07	1330/ 21 hours	10 hours
MRS	1630/ 6 Sept 07	1330/ 21 hours	11 hours
MLS	0030/ 7 Sept 07	1400/ 13+30 hours	10 hours
MTS	1630/ 6 Sept 07	1330/ 22 hours	8 hours +
MFS	1730/ 6 Sept 07	1230/ 19 hours	9 hours +

(Tabs V-1.24,V-3.45, V-4.32, V-5.13, V-7.12, V-8.19, V-9.12)

10. OPERATIONS AND SUPERVISION

a. Operations.

The mishap unit has been deployed with at least one third of it's assets allocated to the Global War on Terror since Oct 2001. The members of this unit are well versed in the deployment cycle and combat operations. The deployment rotation is steady and predictable. Generally, each member knows months in advance when their next deployment will be. Training flights at home station are regular enough to maintain currency. On average, each MC-member will fly 2 training sorties per week. Operations tempo was not a factor.

b. Supervision.

The mission was a typical local training sortie and was appropriately approved by the ADO. The Director of Operations, Lt Col Eugene Becker, was the commander on the night of the mishap and also the MP

11. HUMAN FACTORS ANALYSIS

Human factors are divided into two categories: environmental and individual. Environmental factors include operational issues, logistics or maintenance factors, matters pertaining to egress and survival, and issues associated with facilities and services essential to mission accomplishment. Individual factors can range from physiological or biodynamic issues to psychological and psychosocial concerns. The board considered all the environmental and individual human factors elements contained in Air Force Pamphlet (AFPAM) 91-211, *USAF Guide to Aviation Safety Investigation*, Attachment 8, Human Factors Terms, and analyzed them to identify potentially relevant factors that may have contributed to this mishap. There is no evidence that human factors contributed to this mishap.

12. OTHER AREAS OF CONCERN

a. Environmental Clean Up.

The mishap site was thoroughly restored to eliminate toxins from the soil as a result of a fuel leak from the left auxiliary tank. The team that conducted the restoration removed approximately 320 yards of contaminated soil, excavating to a depth of approximately 8 feet at the deepest point. At approximately 8 feet, they struck water; however, there was no evidence of fuel on the water. The environmental clean-up crew was confident they recovered the fuel before it leached into the water. Upon completion of excavation, soil samples were tested at the bottom and several sides of the excavated site with no evidence of contamination, and the hole was backfilled with clean earth.

13. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Primary Operations Directives and Publications.

AFTTP 3-3.34 Combat Aircraft Fundamentals MH-53M, 01 Apr 2007
TO 1H-53(M)M-1, 31 Jan 2001
AFI 11-2MH-53M, Volume 3, MH-53 Operations, 31 Jan 2001

b. Maintenance Directives and Publications.

Technical Order (T.O.) 1H-53(M)J-2-2, Flight Controls, Hydraulic Power Supply, Transmission, Rotors and Blades
Technical Order (T.O.) 1H-53(M)J-2-4, Illustrated Parts Breakdown
Technical Order (T.O.) 1H-53(M)J-2-6 Scheduled Inspection and Maintenance Requirements USAF MH-53(M)M and MH-53(M)J Helicopters
1H-53(M)J-6WC-3, Combat Phase Work Card #2

Technical Order T.O. 3R4-3-6-3, Overhaul Instructions, Intermediate GearBox PN 65357-07000-042

c. Known or Suspected Deviations from Directives or Publications.

i. **Mishap Crew.** None

ii. **Lead Crew/Others.** None

iii. **Operations Supervision.** None

iv. **Maintenance.** None

13. NEWS MEDIA INVOLVEMENT

Media involvement included several articles in national, regional, and local area newspapers, and one article in the Air Force Times regarding the mishap. Requests to enter Eglin Range were denied. Camera crews on the scene shot footage from the blocked entry point (Tab CC-2.1).

Scott B Greene

21 May 2008

SCOTT B. GREENE, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION
MH-53M S/N 69-05794 ACCIDENT
7 SEPTEMBER 2007

1. Under 10 U.S.C. 2254(d) any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report may not be considered as evidence in any civil or criminal proceeding arising from an aircraft accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

2. OPINION SUMMARY

There is clear and convincing evidence this mishap was caused by the material failure of some of the mounting nuts and studs which secure the intermediate gear box (IGB) to the tail pylon of the aircraft. When the IGB became loose in its mount, the gears in the IGB began a cycle of becoming loosely meshed (possibly unmeshed) and re-meshed, causing minute fluctuations in rotor speed. The cyclical disruption induced a diverging, unstable oscillation in the power turbine speed of one or both engines, forcing the crew to make an emergency landing into a confined area. During power application at the bottom of the emergency approach and prior to touchdown, the anti-torque provided by the tail rotor drive system was lost due to the IGB being loose in its mount and low rotor speed. The aircraft entered a rapid clockwise rotation, contacted the ground, and was damaged extensively. Damage included: separation of the tail pylon, destruction of all main rotor blades, damage to the main rotor components, left main landing gear, and left sponson and auxiliary tank. The crew performed in an exceptional manner throughout the mishap sequence.

3. BACKGROUND

Following 1.2 flight hours of contact, instrument, and emergency procedures training, the mishap aircraft (MA), MH-53M helicopter S/N 69-05794, with its seven-man crew, departed Hurlburt Field at 2336 local time to conduct NVG AIE hoist training at LZ X-ray. The MCP was at the controls and shot an approach with an eastbound course to conduct a practice hoist exfiltration of a simulated ground party.

Approximately 0.3 NM from the LZ, the MTS felt a slight low frequency vibration at a rate of approximately 1-per revolution, which in his judgment, was not severe enough to mention to the crew nor to call a go-around. He stated this vibration was much less severe than the damper malfunctions he had experienced in the past, and was different than what he had experienced on the same tail number 10 days prior. The MCP overshot the approach and came to a hover 75-150 feet east of the LZ, at about 150 feet above the ground and well above the 50-60 ft trees in the area. A few seconds later, while the MC was repositioning the MA to the LZ, the MTS became more concerned about the vibration and called "go around, go around, go around."

4. DISCUSSION OF OPINION:

Clear and convincing evidence shows the IGB had become loose in its mount on the tail pylon due to the material failure of most of the eight nuts and studs used to secure it to the aircraft. During the post mishap evaluation of the IGB, four of the eight nuts were missing. Of the remaining four, two were difficult to remove and two threaded off their studs normally, though the self-locking feature of the latter two nuts was not very effective.

Three of the eight IGB mounting studs were not visible; one was completely missing and two had broken in the nut threads. Two of the other five had pulled out of the center housing due to cracks where they were mounted to the housing. Of the remaining three, one did not have a nut, one had a nut with stripped threads, and one was intact with the nut found installed. Collectively, there were only two studs still attached to the center housing and with nuts on the threads, of which one was stripped (see Figure 2, Stud 6 and 7). Additionally, the counter-sunk screws, which attach the input housing to the center housing, were all stripped or broken. Some or all of these material failures occurred prior to landing and allowed the IGB gears to become intermittently loosely engaged or disengaged in flight at a cyclical rate. With as few as only one stud and nut properly secured (Stud 6), it is possible the IGB armor was the only real structural linkage keeping the IGB mounted to the tail pylon.

All helicopter components are carefully designed to ensure none of the potential vibration functions will serve as the forcing function that causes a component to resonate at any of its harmonic nodes. However, if a component is no longer properly secured, the component itself can reach a catastrophic harmonic or it can induce an unanticipated forcing function, which subsequently causes another component to malfunction, despite the fact the other component is installed and functioning properly. While a forcing function is typically associated with the physical resonance of an object, it can also apply to other properties of the total engineered system such as fuel scheduling.

Clear and convincing evidence shows the IGB became loose in flight, and the gears became loosely meshed as they pushed apart and even may have begun to slip in flight. The IGB gears push apart as they transfer energy, so once the IGB was no longer properly secured to the aircraft, the gears momentarily pushed apart becoming loosely meshed (possibly unmeshed) and then re-meshed and loosely meshed and re-meshed, and so-on, with the IGB armor as the spring to pull them back together on a harmonic cycle driven by the inherent vibration signature of the aircraft and bending characteristics of the tail pylon. The MTS could hear the gears chattering or skipping which he described as an audible "Zzzt, Zzzt, Zzzt" on a cadence of approximately one-per revolution of the main rotor, which was about

2-3 cycles per second, given the main rotor turns at 185 RPM at 100% and the cadence the MTS described. Additionally he could see the entire tail pylon flexing down and up at least nine inches at the same cadence as the audible noise he heard. Post crash analysis of the IGB gears revealed damage to all the teeth on the input gear with up to 0.12 inches shaved off and cracks at the root of many teeth consistent with re-engagement while being driven under power. There is no question the MA was experiencing an impending failure of the tail rotor drive system due to the material failure of the IGB mount. The cockpit indications precisely matched the gear meshing cycle with an accurate display of oscillating fluctuations in the triple tach needles and the torque gauge needles.

To compound the situation, the cyclical torque changes in the tail rotor drive system served as the forcing function which induced a diverging oscillation in the engine speed of one or both engines. Each time the IGB gearing pushed apart becoming loosely meshed, the torque applied to the tail rotor was cyclically interrupted. With the collective position at a constant setting, each time the torque delivered to the tail rotor decreased, the torque was transferred to the main rotor which would momentarily increase an equivalent amount forcing the Nf and Nr to increase. Within a fraction of a second, Nf governing would reduce fuel scheduling to bring the Nf back to the governed setting. As the Nf began to correct itself, the IGB gearing would re-mesh, increasing the torque required to drive the tail rotor, reclaiming the torque provided to the main rotor, thereby reducing the Nr and Nf, and forcing Nf governing to increase fuel flow to keep the Nf at the governed setting. The cyclical change in the torque required to drive the tail rotor drive system coupled with the set load on the main rotor system with the fixed collective position created the "perfect storm" forcing function which induced the hydro-mechanical equivalent of a "PIO" (pilot induced oscillation). The Nf began to oscillate and in less than 30 seconds had diverged to the point it finally tripped the overspeed protection system on one or both engines, which is set at 114-117% Nf.

The cockpit indications reported by the MP precisely match this phenomenon. This was not instrumentation error due to a faulty gauge. The MC could hear the engines and the rotor spooling up and down, eventually causing the aircraft to actually climb and descend as the magnitude increased.

Once the Nf of one or both engines exceeded the overspeed protection limit (above approximately 114-117%), the fuel control(s) would have reduced the fuel flow of the engine(s) to idle as designed, further exacerbating the already complex malfunction. The MA would have experienced the equivalent of a momentary single or dual engine failure. There is significant evidence to show this is what occurred during the latter part of the emergency approach to the LZ.

The MP recalls seeing the torque fluctuating between approximately 10:00 to 12:30 clock positions, which equates to approximately 80 to 105% dual engine. This is equivalent to approximately 160 to 210% torque single engine. However, the single engine power available was less than 130%. Consequently, if one or both engines hit the Nf overspeed protection limit, fuel scheduling would be reduced to idle, the MA would be in a single engine situation with less than single engine power available, and the rotor speed would decay significantly.

Based on the MA's position and ground speed using the data recovered from the mission computer and also based on the observed winds at Duke Field less than five miles away, approximately 15-20 seconds from the LZ, the MA was already below a safe single engine airspeed of 26-31 KIAS (as calculated from Dash One, Figure A-26 and A-34). Using the MP's testimony and the picture he drew and correlating it to the aircraft's position and ground speed from the mission computer data, the engine and rotor speeds had achieved an oscillating fluctuation of approximately 80-120% about 10-15 seconds from the LZ. As the MA came over the LZ and the MTS called clear of the trees, the MP saw 70% Nr and Nf on his triple tach, and the Nr was not coming back up. The MA was in a single engine power situation, at best, and the rotor had drooped. The aircraft started a slight yaw to the right, due to loss of tail rotor effectiveness below 82% Nr. The MP immediately bottomed the collective to regain rotor speed to ensure aircraft control upon landing. With the torque on the drive train reduced to minimum, the gears in the IGB re-meshed making an audible "tunk" as reported by the MTS, the spooling stopped, and the aircraft descended rapidly.

At 20-25 ft above the LZ, the pilot pulled the collective to the mechanical stop to arrest the rate of descent to cushion the landing. The MA entered a rapid right yaw due to a combination of loss of tail rotor effectiveness secondary to low rotor speed and loss of tail rotor drive due to the condition of the IGB. The MA spun clockwise and contacted the ground in a hard landing. The MA became airborne again, continued its clockwise rotation, touched down a final time, and rolled up on its left side allowing all main rotor blades to contact the ground. The MA rolled back to its right and came to rest on its landing gear. At some point during the mishap sequence both engines had stopped running or were shut down. The aircraft was damaged extensively during the mishap sequence.

The MC egressed, proceeded to safe location, provided self-aid and buddy care to each other, and called for help using cell phones and a survival radio. The MTS and MFS were flown separately by two life flight helicopters to hospitals in the local area, treated, and released the next day. The other five members of the MC were taken to Eglin AFB hospital, treated and released. The emergency response from all agencies was exceptional.

In troubleshooting the cause of the engine oscillations, the board pursued three avenues: an expert at the Air Force Institute of Technology (AFIT), an expert at Navy Depot (NADEP) Cherry Point, and a T64 Engine Component Improvement Program (CIP) Engineering Status Report, 2 Dec 1976 to 5 May 1977. The AFIT expert hypothesized that given the right stimulus, the situations described by the board president are theoretically possible. NADEP published a message which stated, "...if the cyclic input is at a frequency not associated with

the design of the governor, the governor and hence the engine rotating system may not react with precision to offer a steady Nf and may in fact diverge." Finally, the CIP detailed a phenomenon during CH-53E tests in 1976-77, nearly identical to what had occurred with the MA. The test pilots had encountered diverging Nf oscillations on the T64-GE-415 engine at critical 2-Hertz mode flight conditions, which had been induced by the lead-lag dampening characteristics of the helicopter's 7-blade rotor head. The problem was fixed with a relatively simple engine modification. Note that though there are similarities between the T64-GE-100 and the 1977 T64-GE-415, the MH-53M does not normally operate in 2-Hertz mode flight conditions, so there was no need to make a similar modification, nor is there a need now.

There is an unresolved discrepancy in the specified torque required on the nut-stud combination used to mount the IGB to the tail pylon. The values used by the Air Force (200 inch pounds) differed from the current 2004 technical drawing (140-145 inch pounds). Historical drawings from 1968 supplied by Sikorsky did not specify a torque value for the nuts used to mount the IGB. In the absence of a specified torque value, the nut would have been torqued IAW the Sikorsky standard. In 1976, Sikorsky changed the nut, and established a torque value of 140-145 inch pounds. The change was classified as a Class II change, and a government representative reviewed and signed the engineering order. This new value was subsequently included on the updated drawings in 1984 and again on the drawings in 2004, and yet the AF TO still specified an installation torque 55-60 inch pounds greater. It's possible the hardware may have failed due to the use of the greater installation torque value; however there is no history of IGB mounting failures in the USAF, USN, Israeli, or German H-53 programs. The impact of the AF's use of a greater than specified torque value and the sufficiency of the process for Class II changes in 1976 and 1984 could not be determined.

There is no published emergency procedure for the specific conditions the MC encountered. There are no previously reported Navy, Marine, or Air Force mishaps in which the phenomenon of loosely meshed or unmeshed gears in the IGB induced a diverging Nf oscillation in a 6-blade H-53. The MC's performance throughout the mishap sequence was exceptional and prevented what could have resulted in far worse injuries and greater damage to the aircraft.

In closing, it's important to note all of the members of the MC were interviewed and each independently stated Pavelow operations and maintenance personnel remain as dedicated as ever, if not more so, with the pending retirement of the aircraft.

4. CONCLUSION:

There is clear and convincing evidence this mishap was caused by the material failure of some of the mounting nuts and studs which secure the intermediate gear box to the tail pylon of the aircraft. When the IGB became loose in its mount, the gears in the IGB began a cycle of becoming loosely meshed (possibly unmeshed) and re-meshed, interrupting the torque required by the engines, inducing a diverging, unstable oscillation in the power turbine speed of one or both engines, forcing the crew to make an emergency landing into a confined area. During power application at the bottom of the emergency approach and prior to touchdown, the anti-torque provided by the tail rotor drive system was lost due to the IGB being loose in its mount and low rotor speed. The aircraft entered a rapid clockwise rotation, contacted the ground, and was damaged extensively. The crew performed in an exceptional manner throughout the mishap sequence.

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21 May 2008

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